ADA043298

AD NO.
DDC FILE COPY

(12)

NAMRL - 1235

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION

Tommy R. Morrison, LT MSC USN

and

Gerald M. Long, LT MSC USNR

April 1977

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

Approved for public release; distribution unlimited.

Morrison, Tommy R., LT MSC USN 1977
Gerald M. Long, LT MSC USNR

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN 1977
Gerald M. Long, LT MSC USNR

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN 1977
Gerald M. Long, LT MSC USNR

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN 1977
Gerald M. Long, LT MSC USNR

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Approved for public release; distribution unlimited.

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION

LT Tommy R. Morrison, MSC, USN

and

LT Gerald M. Long, MSC, USNR

Naval Medical Research and Development Command
MF51.524.004 2011

Approved by

Ashton Graybiel, M.D.
Assistant for Scientific Programs

Released by

Captain R. E. Mitchel, MC, USN
Commanding Officer

6 April 1977

Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

SUMMARY PAGE

PROBLEM

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation.

FINDINGS

Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Opinions or conclusions contained in this report are those of the authors and do not necessarily reflect the view or the endorsement of the Navy Department.

Gerald M. Long's present address is: Psychology Department, Stanford University, Stanford, California 94305.

INTRODUCTION

The influence of caffeine or caffeine derivatives on human and sub-human behavior has been investigated in numerous studies in the last 40 years. These have looked at such diverse phenomena as the effects of the drug on olfactory sensitivity in dogs (20), sexual performance and maze learning retention in rats (31), (21), prolonged driving performance in an automobile simulator (23), prolonged visual monitoring (2), (12), general attention in man (24), prolonged simultaneous monitoring and tracking performance in a simulated aviation trainer (22), (10), and other assorted physiological or behavioral measures both in man and the lower animals (5), (17), (30), (24), (26), (28). Pharmacology handbooks categorize caffeine as a central nervous system stimulant (14), (27). In the previous studies in which the drug has been reported to produce an effect, the effect has been described as that of a central stimulant which increases alertness and shortens reaction time. Caffeine has consistently resulted in improved performance in prolonged tasks; e.g., 4 hour task (2), 6 hour task (10), 7 hour task (22), and a 90 minute task (23).

There is considerable electrophysiological evidence that caffeine affects physiological correlates of psychological states of alertness. Caffeine has been reported to affect the EEG response (9) and the recruiting response (8). Maiti & Domino (15) found caffeine to produce a prolonged afterdischarge following electrical stimulation of isolated cortical tissue from dogs.

In the area of human visual perception, previous studies have demonstrated a marked effect due to rather mild doses of caffeine. Kleman, Diamond, and Smith (13) reported caffeine administration (3 grains) to reduce the normal enhancement effect in simultaneous contrast. Diamond & Cole (6) obtained progressively lower mean absolute detection thresholds with increasing amounts of caffeine ingestion (0, 1.5, and 3.0 grains).

Only one study was found which investigated the effects of caffeine on dark adaptation in the human eye. In this short summary article, Ditchburn & Power Steele (7) reported mixed effects due to caffeine upon foveal thresholds obtained during the first minute of dark adaptation for two Ss.

Due to the extensive and frequent use of coffee by naval personnel in the operational environment; e.g., prior to and during night flights, watchstanding, and night driving, the present investigators were interested in examining the effects of caffeine on dark adaptation. The present investigation was designed to examine the effects of caffeine upon dark adaptation during approximately the first 30 minutes of exposure to darkness.

EXPERIMENT I

The first experiment employed caffeine in capsulated form.

METHOD

Subjects. Three Ss (ages 25-26 years) employed in this investigation were staff members of the Naval Aerospace Medical Research Laboratory. Two Ss were slightly near-sighted (corrected to 20/20), while the other was 20/20 uncorrected. Near-sighted Ss performed the experimental task with corrective lenses. Ss' weights ranged from 170 - 185 pounds. While one S was a relatively heavy coffee drinker (5-8 cups/day), the other two Ss were moderate coffee drinkers (2-4 cups/day). Two of the Ss also served as the experimenters.

Apparatus. A Goldman-Weekers Adaptometer manufactured by Haag-Streit Co. (Model No. H6501) was employed. The circular test stimulus was 5.5° in diameter and presented 11° below a small, red fixation light. The maximum luminance of the test stimulus was measured to be 0.78 ft. -L by employing a calibrated Spectra Brightness Spot Meter (Model UB - 1/4°) manufactured by Photo-Research Corp. According to the adaptometer's specifications, the test stimulus luminance can be reduced over 7 log units by means of a calibrated wedge filter. The recording of extrafoveal threshold brightness throughout each experimental session was accomplished using a constantly revolving recording drum on which E was able to mark the position of the wedge filter by a slight lateral pull of the wedge control knob.

Measurements of the test stimulus luminance were made with the Spot Meter at every 0.2 log increment over the upper log unit interval (log 0 - log -1). These were the lowermost luminances which lie within the Spot Meter's "calibrated" range of measurements where accuracy is specified as being within 5 percent. A linear-log relationship was found to exist within this interval between the adaptometer log intensity settings and the obtained luminance intensities of the test stimulus; e.g., log 0 setting = 0.78 ft. -L and log-1 setting = 0.078 ft. -L.

Procedure. Each S was run for 12 experimental sessions, one per day, during a 3-4 week period. The three treatment conditions which were randomly mixed over the 12 sessions (four each) consisted of a lactose placebo condition, a 100 mg caffeine condition, and a 300 mg caffeine condition. The latter two conditions were equivalent to the average amount of caffeine in one and three cups of brewed coffee respectively (16). A double-blind design was used so that, for any given session, neither S nor E knew whether the identical looking gelatin capsules contained the placebo or caffeine. All sessions were run at approximately the same time of day in the early morning, and Ss were instructed to neither eat nor drink anything in the morning, prior to the experimental run. The experiment was performed in an air-conditioned dark room and the temperature was maintained at a comfortable level.

Prior to the beginning of the experiment, all Ss were familiarized with the apparatus and given at least one 29 minute practice session on the absolute detection task. The 29 minute dark adaptation run was the same for all sessions

and Ss. The session was begun 15-20 minutes following the ingestion of the gelatin capsule assigned for that day. For the entire session, S performed his task monocularly, his left eye being occluded by an eye patch. S was initially light-adapted at a luminance of 1000 ft-L for a 2 minute period. Immediately following the termination of this pre-adapting light, E steadily increased the brightness of the extrafoveal circular target until S reported its presence by depressing a signal buzzer. This stimulus value was then immediately marked on the recording drum by E. Next, E quickly reduced the intensity of the test stimulus and then began increasing the intensity until S responded again. During the first 4 minutes following the termination of the pre-adapting light, detection responses were obtained every 5-7 seconds in order to track the very rapid rate of change in S's absolute threshold at this time. S's responses obtained during each 30-second interval were averaged to provide eight threshold estimates over the initial 4-minutes of dark adaptation. During the 5-29 minute period of dark adaptation, 4 threshold measures were taken every other minute and averaged to provide 13 dark adaptation threshold estimates during this time period. This procedure was developed during earlier pilot work and proved adequate for describing the progression of Ss dark adaptation.

RESULTS OF EXPERIMENT I

For each treatment condition, corresponding threshold estimates were averaged across sessions. These mean threshold estimates for the individual Ss are presented in Figures 1, 2 and 3, and in Table A1 (Appendix A). Average threshold estimates for all 3 Ss are presented in Figure 4.

For each S, the sign test (two-tailed) was used to make the following between treatment comparisons: (1) placebo with 100 mg caffeine, (2) placebo with 300 mg caffeine, and (3) 100 with 300 mg caffeine. For each S, mean threshold estimates for one treatment were paired with the appropriate mean threshold estimates of another condition with respect to time. The mean log threshold estimates presented in Table A1 (Appendix A) were used in the sign tests.

The results of the sign tests are presented in Table 1. As shown in Table 1, for S T.M., mean threshold estimates for 300 mg and 100 mg caffeine were lower than those for placebo ($p < .005$). S T.M.'s mean log threshold estimates were averaged within each treatment condition and resulted in the following mean mean log threshold estimates: (1) -3.40 for placebo, (2) -3.48 for 100 mg caffeine, and (3) -3.53 for 300 mg caffeine. On the average, then, mean mean log threshold estimates for 300 mg were 0.13 and 0.05 log units lower than that for placebo and 100 mg, respectively, while the mean mean threshold estimate for 100 mg caffeine was 0.08 log unit lower than that for placebo.

For S G.L., mean log threshold estimates for 300 mg and 100 mg caffeine were lower than those for placebo ($p < .005$ and $p < .05$, respectively). S G.L.'s mean log threshold estimates were averaged within each treatment condition and resulted in the following mean mean log threshold estimates: (1) -3.39

for placebo, (2) -3.42 for 100 mg caffeine, and (3) -3.46 for 300 mg caffeine. The mean mean log threshold estimate for 300 mg was 0.07 and 0.04 log units lower than that for placebo and 100 mg, respectively, while the mean mean threshold estimate for 100 mg caffeine was 0.03 log unit lower than that for placebo.

For S S.H., mean log threshold estimates for 100 mg caffeine were lower than those for placebo ($p < .05$); however, mean log threshold estimates for 300 mg caffeine were not lower than those for placebo. S S.H.'s mean log threshold estimates were averaged within each treatment condition to produce the following mean mean log threshold estimates: (1) -3.87 for placebo, (2) -3.90 for 100 mg caffeine, and (3) -3.90 for 300 mg caffeine.

By visually examining each raw data sheet, the rod-cone break was found to have occurred consistently at approximately the end of the fourth minute following exposure to darkness. However, due to the present method of averaging threshold estimates within 30 second intervals during the first 4 minutes of dark adaptation, the plotted mean log threshold estimates (see Figures 1, 2, 3 and 4) do not reflect the rod-cone break apparent in the raw data. The sign test (two tailed) was used to compare differences between the three conditions for each S during the initial four minutes of dark adaptation. No differences between conditions were obtained during this period of dark adaptation.

Next, the sign test (two-tailed) was used to compare differences between conditions for each S during the 5-29 minute portion of dark adaptation and these results are presented in Table 2. For S T.M., mean log threshold estimates for both 300 mg and 100 mg caffeine were lower than those for placebo ($p < .005$). For S G.L., mean log threshold estimates for the 300 mg and 100 mg caffeine conditions were lower than those for placebo ($p < .005$ and $p < .05$, respectively). With S S.H., only the 100 mg threshold estimates were lower than those for placebo ($p < .005$).

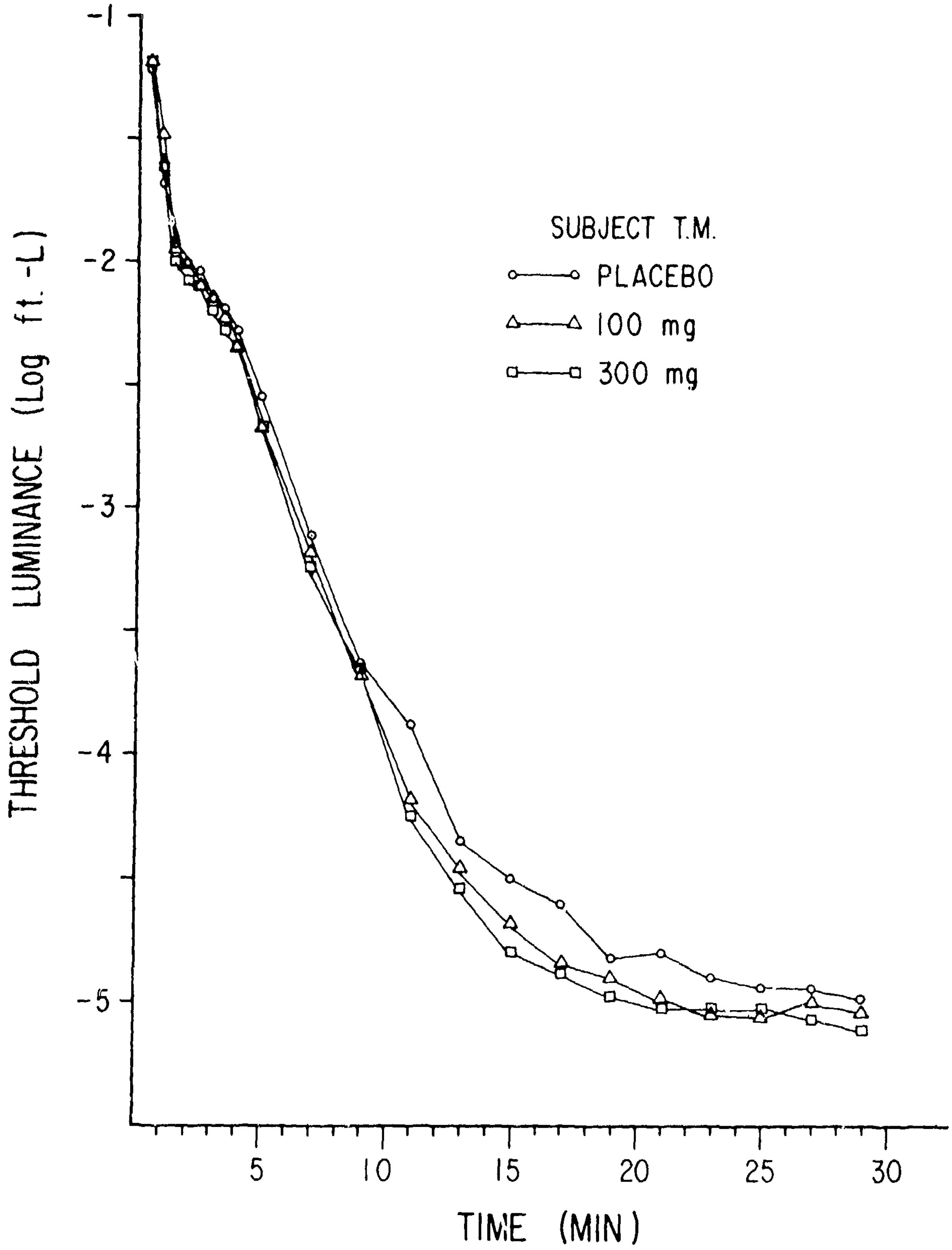

Figure 1. Thresholds in log ft.-L as a function of time for placebo, 100-mg., and 300-mg. caffeine.

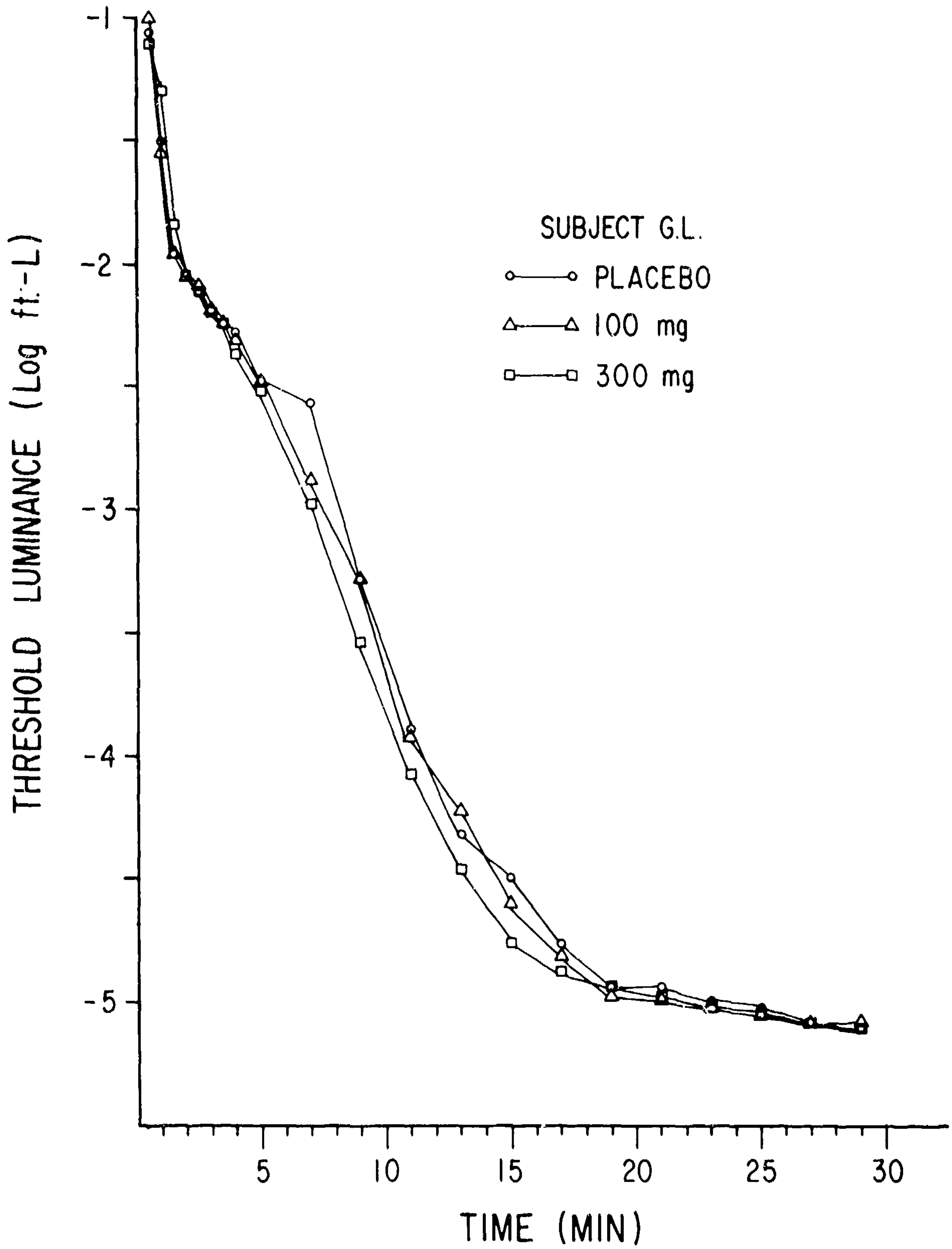

Figure 2. Thresholds in log ft.-L as a function of time for placebo, 100-mg., and 300-mg. caffeine.

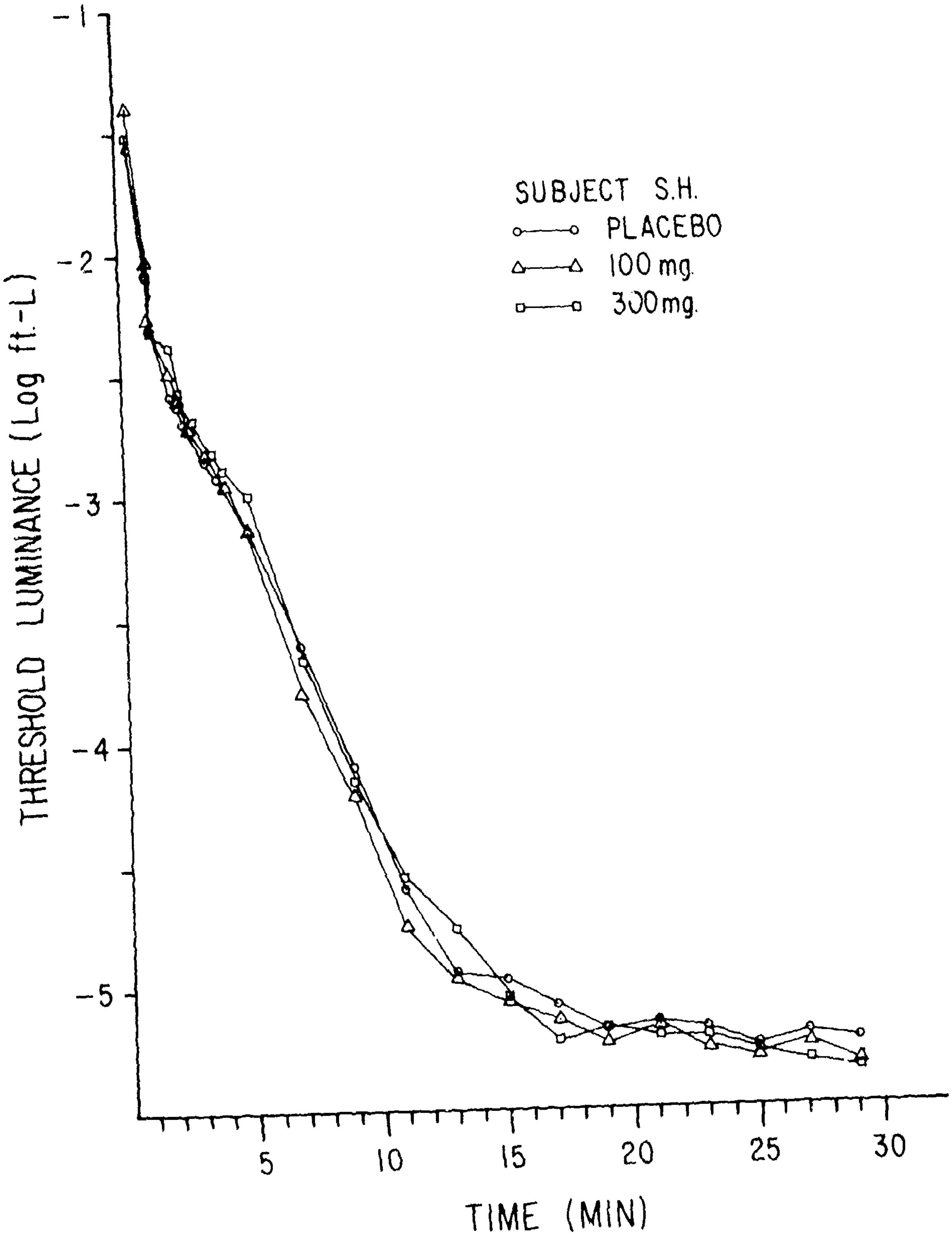

Figure 3. Thresholds in log ft.-L as a function of time for placebo, 100-mg., and 300-mg. caffeine.

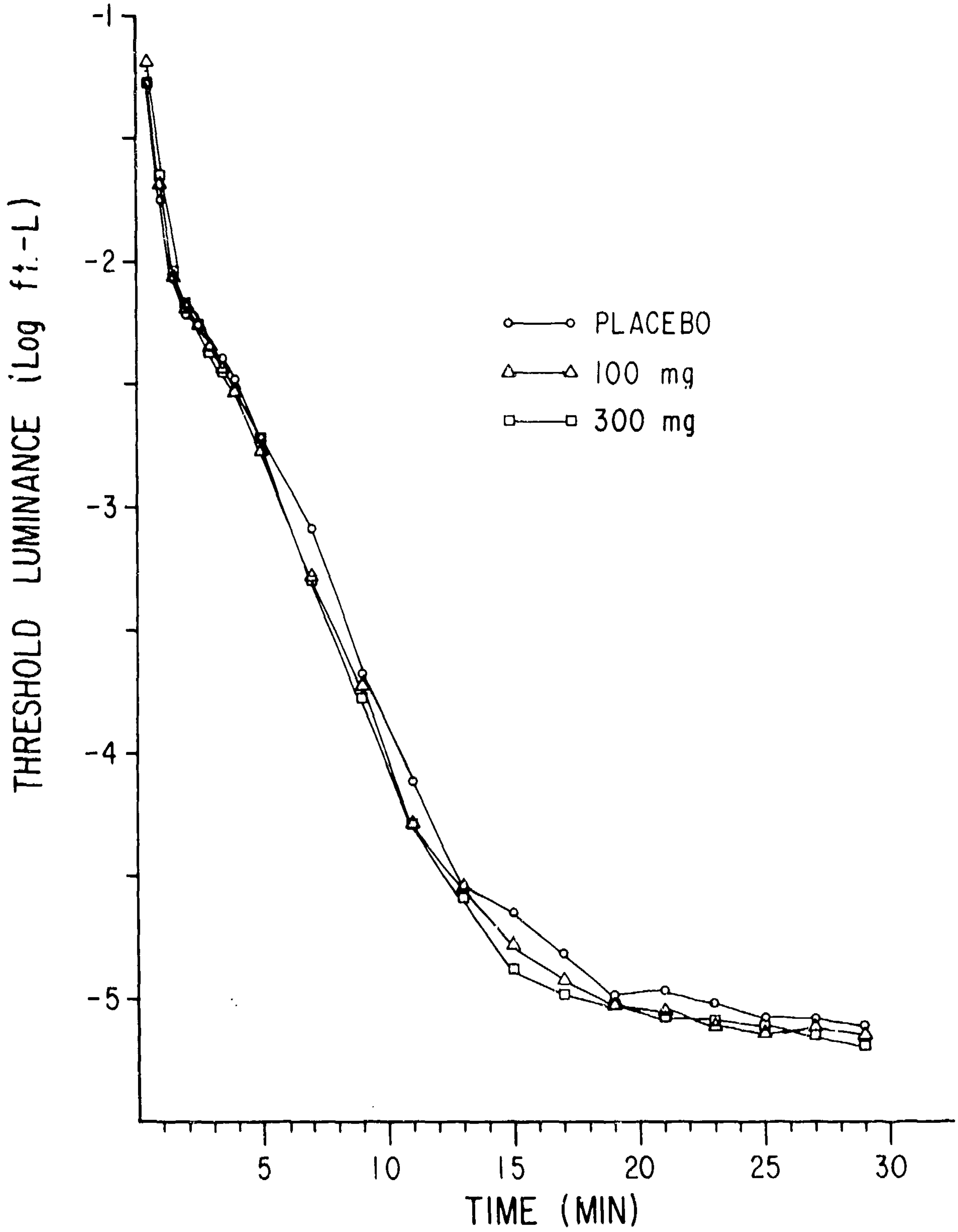

Figure 4. Mean thresholds in log ft.-L for Ss T.M., G.L., and S.H. as a function of time for placebo, 100-mg., and 300-mg. caffeine.

Table 1

Results of Sign Tests for Experiment I Computed Over the Full 29-min. of Dark Adaptation

S	Number of Times 300 mg. < Placebo	Number of Times 300 mg. < 100 mg.	Number of Times 100 mg. < Placebo
T.M.	19**	14 (2 ties)	18 (1 tie)**
G.L.	17 (2 ties)**	13 (3 ties)	16*
S.H.	11 (2 ties)	7	15 (1 tie)*

* $p < .05$
** $p < .005$
N = 21

Table 2

Results of Sign Tests for Experiment I Computed Over the 5 - 29 min. Period of Dark Adaptation

S	Number of Times 300 mg. < Placebo	Number of Times 300 mg. < 100 mg.	Number of Times 100 mg. < Placebo
T.M.	13**	9	13**
G.L.	11 (2 ties)**	10	11*
S.H.	9 (1 tie)	4	13**

* $p < .05$
** $p < .005$
N = 13

EXPERIMENT II

The analysis of Experiment I indicated that caffeine consumption in capsulated form resulted in lower threshold measures during the first 29 minutes of dark adaptation. Due to the prevalent consumption of coffee among naval personnel, often prior to and during night operational tasks, it was of interest to determine whether lower dark adaptation thresholds would result from caffeine consumption in the form of coffee. Experiment II was undertaken to answer this question.

METHOD

Subjects. Three Ss were employed in this investigation. Two Ss (ages 24 and 43 years) were staff members at the Naval Aerospace Medical Research Laboratory, while the other S (age 24) was a Naval Flight Officer Candidate currently in training at the Naval Air Station, Pensacola, Florida. All Ss' vision was 20/20 uncorrected, and Ss' weights were 145, 165, and 175 pounds. S J.S, and S D.V., usually drank approximately 6 cups of coffee per day, while S B.F. drank 3 cups per day.

Apparatus. The Goldman-Weekers Adaptometer configured identically as in Experiment I was employed.

Procedure. The two treatment conditions consisted of consumption of either 3 cups of caffeinated or 3 cups of decaffeinated coffee. The order of treatment administration was block randomized over eight sessions such that within two blocks each treatment condition occurred twice with neither condition having been presented more than twice in succession. Ss J.S. and D.V. received the complete two blocks; however, S B.F., due to his flight training obligations, was unable to perform the fourth experimental session under decaffeinated coffee. Therefore, for S B.F., the data from the fourth caffeinated session were not included in the analysis.

A double blind design was again employed. Each S received a schedule in accordance with which he prepared either 3 cups of caffeinated coffee, or 3 cups of decaffeinated coffee for each daily session. The method of coffee preparation was identical for both coffees. In preparing each cup of coffee S emptied two vials, each containing 5 grams of coffee, into a new paper filter which was supported over a pot. Next, S poured 6 ounces of steaming water over the 10-grams of coffee and the brewed coffee drained into the pot below (drip brew method). The S then consumed this cup of coffee, brewed another cup using a new filter in the above manner, drank the coffee, then brewed and drank the third cup of coffee. The 3 cups of coffee for a given session were consumed within a 40-min. time period.

Martinek & Wolman (16) reported that the caffeine content of four commercial brands of ground coffee ranged from 1.1 to 1.5 percent. In addition they found that caffeine content varied little (101 to 119 mg/cup) as a function of method of brewing coffee (percolator, vacuum, and drip methods) and that virtually all the caffeine was extracted from the ground coffee via these preparation methods. Therefore, the caffeine content per cup should have approximated 100 mg in the present experiment. E was cognizant of neither the type coffee S brewed and consumed for each session, nor the order of treatment administration employed during the experiment.

The Ss were requested either to take breakfast (no coffee, tea, or colas) every morning or never at all during the morning prior to the experimental sessions. If S chose to take breakfast he was requested to do so in similar quantities of the same type food. The reasoning for this prescribed breakfast habit during the experiment were: (1) absolute thresholds have been found to increase in glucose deficient Ss (19), (2) absorption rate of drugs in the gastrointestinal tract is affected by food, or lack thereof (3), and (3) to examine caffeine effects under increasingly realistic conditions. Thus, by strongly requesting that each S either always or never consume similar breakfasts prior to each experimental session, possible differential effects resulting from breakfast consumption on one day but not another for a particular S were considered adequately controlled within each S. All Ss participated voluntarily and were cooperative Ss.

Two Ss (ages 24 and 43 years) were smokers, and were requested not to smoke during the morning prior to the experimental session. Although absolute thresholds have been found to increase immediately following the smoking of a single cigarette thresholds returned to their previous normal level after restoration of oxygen supply (18), (25). All Ss normally drank their coffee black, and did so throughout this experiment.

Prior to the beginning of the experiment, all Ss were familiarized with the apparatus and given one practice session on the absolute detection task. Each S rested 15 minutes following the third cup and then began the experimental session (8:00 a.m.). The 2 minute pre-adapting condition and the 29 minute dark adaptation run were the same for all Ss for all treatment conditions and were identical to those employed in Experiment I.

RESULTS OF EXPERIMENT II

Log threshold measures were averaged within the time intervals specified in Experiment I producing a mean log threshold estimate for each of the 21 time intervals per condition per S (see Table B1, Appendix B). The mean data for each S are presented in Figures 5, 6 and 7, and the mean data averaged across Ss are presented in Figure 8.

The sign test (two-tailed) was employed to test the differences between the pairs of mean log threshold estimates for the caffeinated and decaffeinated coffee conditions. The data presented in Table B1 (Appendix B) were used in sign test computations. Results of the sign tests are presented in Table 3. For S B.F., the mean log threshold estimates of the caffeinated condition were lower than decaffeinated ($p < .005$). The mean log threshold estimates were averaged within each treatment condition for each S. The resulting mean mean log threshold estimates for caffeinated vs decaffeinated conditions were -3.96 and -3.92 for S D.V., -4.05 and -3.94 for S B.F., and -3.73 and -3.73 for S J.S., respectively.

The sign test (two-tailed) was used to compare differences between the two conditions for each S during the initial four minutes of dark adaptation; i.e., prior to the rod-cone break. No differences were obtained between the two conditions. Next, the sign test (two-tailed) was used to compare differences between conditions during the 5-29 minute period of dark adaptation; i.e., following the rod-cone break. For S B.F., threshold estimates for the caffeinated condition were lower than decaffeinated ($p < .005$) during the 5-29 minute portion of dark adaptation.

DISCUSSION

The results of the above two experiments indicated that within certain Ss caffeine consumption in moderate dosages resulted in lower threshold measures during dark adaptation. With capsulated caffeine, in two of the three Ss, thresholds obtained under 300 mg and 100 mg caffeine conditions were lower than placebo thresholds. For the other S, only mean thresholds for 100 mg caffeine were lower than placebo. With caffeine presented in the form of coffee mean thresholds for the caffeinated condition were consistently lower than thresholds for the decaffeinated condition in one of three Ss.

When the caffeine enhancement effect occurred, it was found to be significant only during the portion of the curve following the rod-cone break. This portion of the dark adaptation curve is attributable to rod adaptation (11). As mentioned previously, Diamond & Cole (6) obtained lower foveal detection thresholds under caffeine than under placebo. Many differences exist between the present study and Diamond & Cole (6); e.g., in the present study the test stimulus was presented at 11° eccentricity and stimulated few cones relative to the number of rods stimulated (4). Therefore, no comparison between Diamond & Cole's (1970) results and the present results is made.

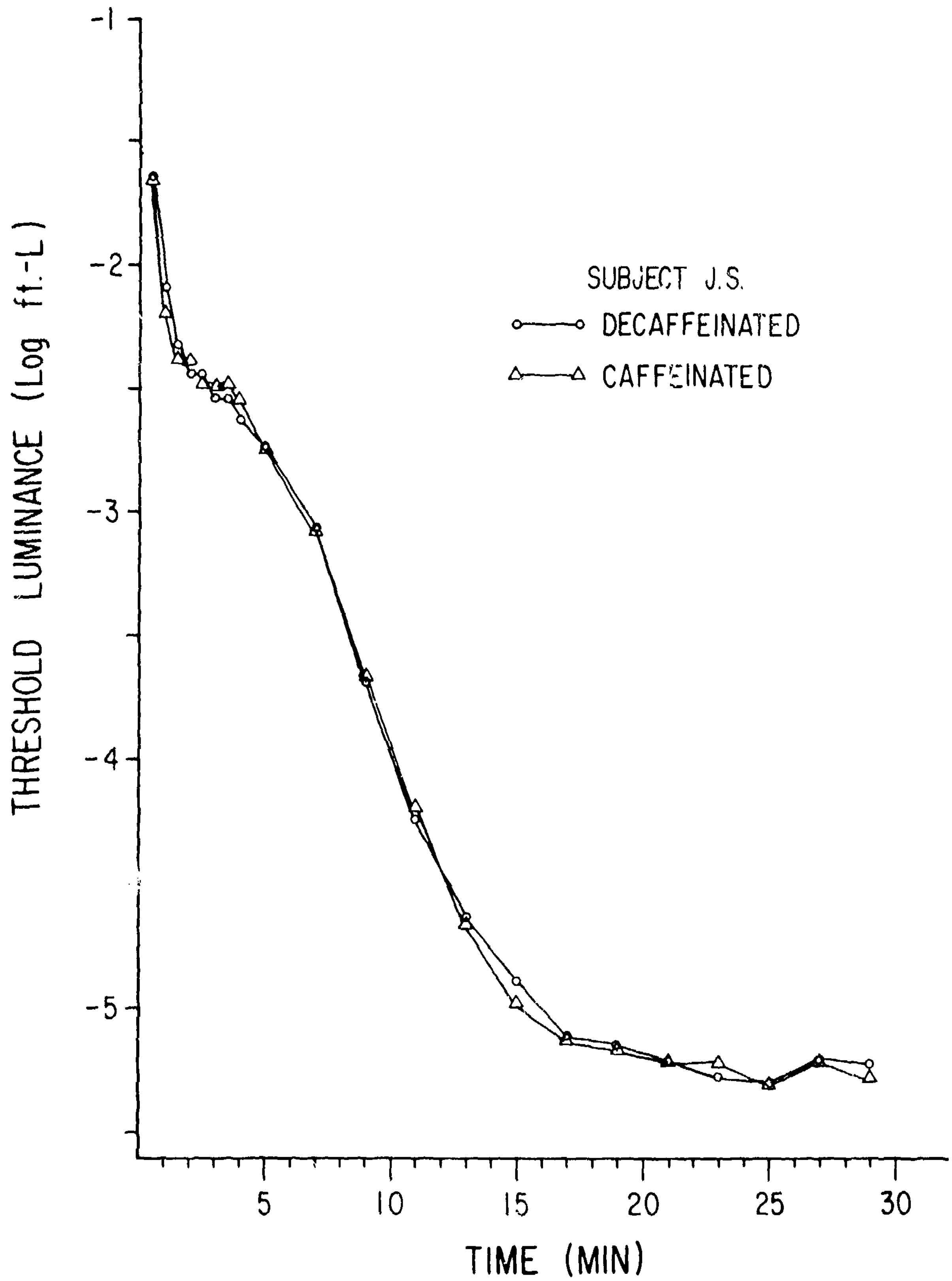

Figure 5. Thresholds in log ft.-L as a function of time for 3 cups decaffeinated and 3 cups caffeinated coffee.

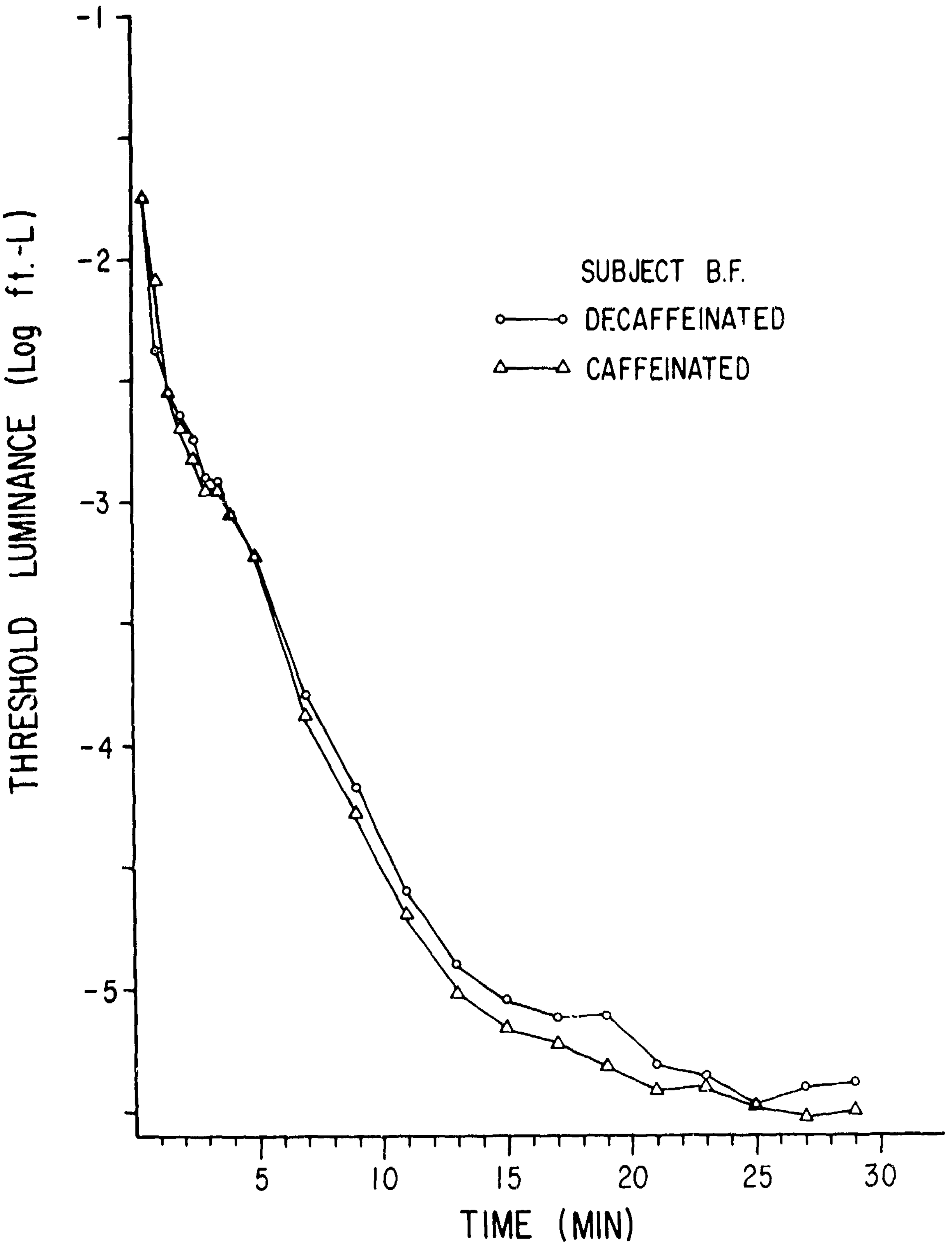

Figure 6. Thresholds in log ft-L as a function of time for 3 cups decaffeinated and 3 cups caffeinated coffee.

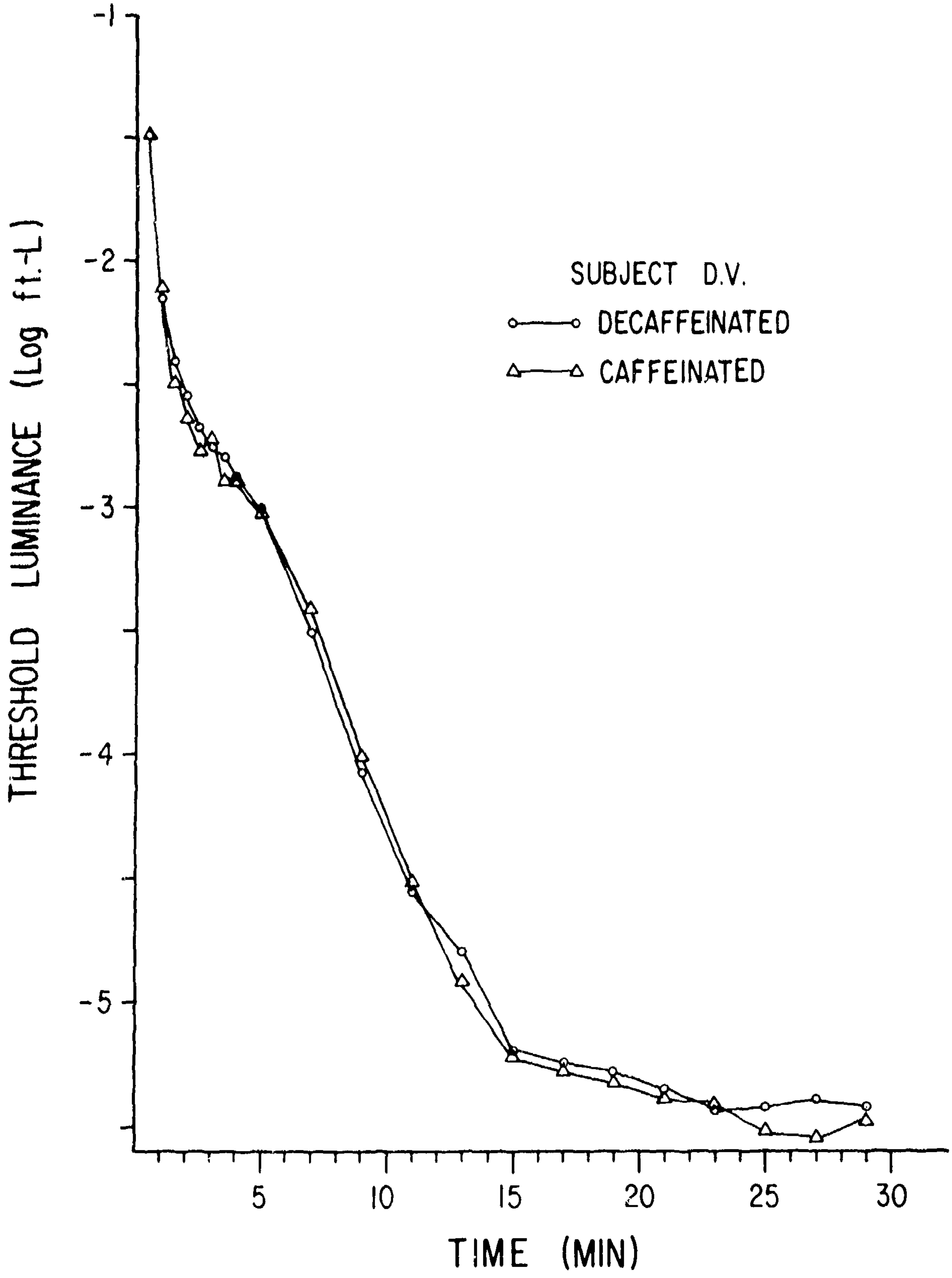

Figure 7. Thresholds in log ft.-L as a function of time for 3 cups decaffeinated and 3 cups caffeinated coffee.

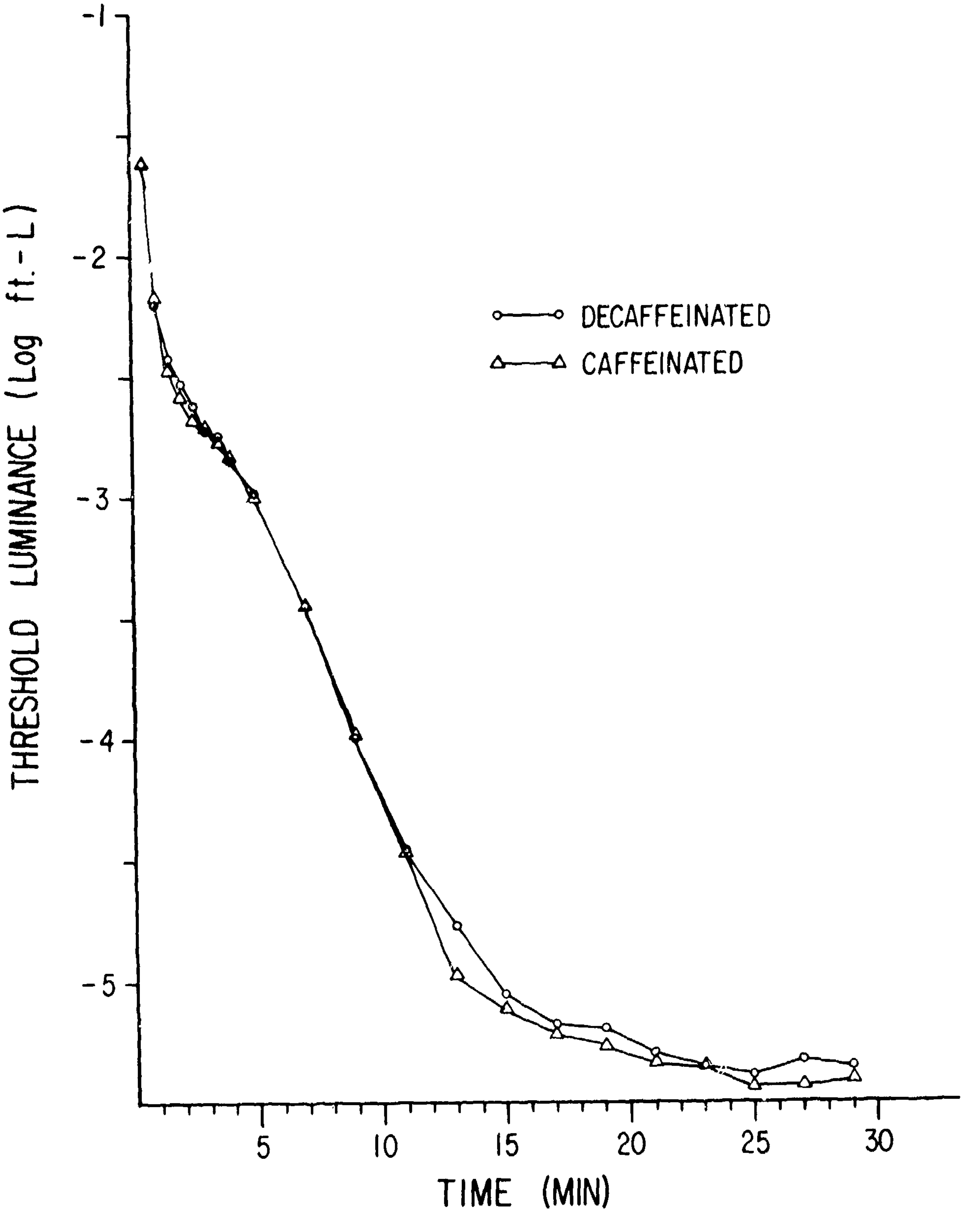

Figure 8. Mean thresholds in log ft.-L for Ss J.S., B.F., and D.V. as a function of time for 3 cups decaffeinated and 3 cups caffeinated coffee.

Table 3

Results of Sign Tests for Experiment II Computed Over the Full 29-min. Dark Adaptation

S	Number of Times Caffeinated < Decaffeinated
D.V.	14 (1 tie)
B.F.	17 (3 ties)**
J.S.	12 (1 tie)

** $p < .005$

$N = 21$

The question arises - what is the practical significance of detecting a target at -5.50 rather than -5.38 ft. -L, as occurred in S B.F. for the caffeinated and decaffeinated conditions, respectively after 29 minutes of dark adaptation? Stating the question differently - how much further away should S B.F. be able to detect an anti-collision light at night as a result of consuming 3 cups of caffeinated coffee? In order to answer this question, the ft. -L thresholds were converted to their equivalent ft. -C values with which the inverse-square law could be used to calculate the distance at which the illuminance from a given light source equals the illuminance equivalent to the above thresholds for S B.F.

According to Walsh (29) the luminance of a uniform diffuser may be expressed in terms of flux emitted by it per unit area. If we assume the opal diffuser of the present test target to be a uniform diffuser, the following conversions can be performed (see (29), p. 137). A uniform diffuser with a luminance of I cd/ft^2 produces an emitted flux of πI lumens/ft^2. One ft. -L equals 1/ π cd/ft^2; therefore, for a uniform diffuser with a luminance of 1 ft. -L its flux emitted would equal π (1/ π) lumen/ft^2, or, 1 lumen/ft^2. One lumen/ft^2 equals 1 ft. -C. Therefore, for the present example, assuming a uniform diffuser, the ft.-L threshold values can be converted to equivalent ft. -C values; i.e., -5.50 and -5.38 log ft. -C for the caffeinated and decaffeinated conditions, respectively.

The Grimes lamp # 42895A - 16870 has been used in anti-collision lighting systems on Navy aircraft. This lamp has a candlepower of 1,237 candelas. By employing the inverse-square law, one can calculate the distance from this lamp at which the illuminance equals that required for detection by S B.F. under decaffeinated and caffeinated conditions. At a distance of 3.75 statute miles from the given lamp the illuminance equals 3.16228^{-6} ft.-C (-5.50 log ft.-C); and at a distance of 3.26 statute miles the illuminance equals 4.16894^{-6} ft.-C (-5.38 log ft.-C). Thus, based on the present results, and excluding other factors, e.g., atmospheric conditions, it would be predicted that S B.F. would detect the anti-collision light at 0.49 statute miles further away after consuming 3 cups of caffeinated coffee. This is a 15 percent increase in range of detection at night for S B.F.

Additional descriptive information is provided in TAble C1 (Appendix C) in which Ss are grouped according to their previous coffee consumption and smoking habits.

In summary, the present investigations produced no evidence of any detrimental effects of caffeine upon dark adaptation thresholds. Where caffeine effects were obtained, they were in the direction of lowered detection thresholds, which can be calculated in terms of increased distances at which target detection should occur at night. It is uncertain as to how long the caffeine enhancement effect would persist; however, the biologic half-life of caffeine in man has been found to be, on the average, 3.5 hours (1).

CONCLUSIONS

1. Within certain Ss caffeine consumption resulted in lower detection thresholds during dark adaptation. The caffeine enhancement effect was statistically significant only during the portion of the dark adaptation curve following the rod-cone break.

2. Ss who exhibit a caffeine enhancement effect should be able to detect a given target light source in the dark at a further distance as a result of caffeine consumption. The increased range of target detection may be of practical significance.

3. No evidence was found for a detrimental effect of caffeine upon dark adaptation.

REFERENCES

1. Axelrod, J., & Reichenthal, J. The fate of caffeine in man and a method for its estimation in biological material. Journal of Pharmacology and Experimental Therapeutics, 1953, 107, 519-523.

2. Baker, W. J., & Theologus, G. C. Effects of caffeine on visual monitoring. Journal of Applied Psychology, 1972, 56, 422-427.

3. Bonnycastle, D. D. Intimate study of drug action: absorption and distribution. In: J. R. D. Palma (Ed.), Drills Pharmacology in Medicine. New York: McGraw-Hill Book Co., 1965, pp 16-25.

4. Brown, J. L. The structure of the visual system. In: Graham, C. H. (Ed.), Vision and Visual Perception. New York: John Wiley and Sons, Inc., 1965, pp 39-59.

5. Cheney, R. H. Reaction time behavior after caffeine and coffee consumption. Journal of Experimental Psychology, 1936, 19, 357-369.

6. Diamond, A. L., & Cole, R. E. Visual threshold as a function of test area and caffeine administration. Psychonomic Science, 1970, 20, 109-111.

7. Ditchburn, R., & Power Steele, E. J. The effect of caffeine and bromide on dark adaptation. Nature, 1941, 147, 745-746.

8. Gerber, C. J. Effect of selected excitant and depressant agents on the cortical response to midline thalamic stimulation in the rabbit. Electroencephalography & Clinical Neurophysiology, 1961, 13, 354-364.

9. Gibbs, F. A., & Maltby, G. L. Effect on the electrical activity of the cortex of certain depressant and stimulant drugs - barbituates, morphine, caffeine benzedrine and adrenalin. Journal of Pharmacology and Experimental Therapeutics, 1943, 78, 1-10.

10. Hauty, G. T., & Payne, R. B. Mitigation of work decrement. Journal of Experimental Psychology, 1955, 49, 60-67.

11. Hecht, S. Rods, cones, and the chemical basis of vision. Physiological Review, 1937, 17, 239-290.

12. Keister, M. E., & McLaughlin, R. J. Vigilance performance related to extraversion-introversion and caffeine. Journal of Experimental Research in Personality, 1972, 6, 5-11.

13. Kleman, J. P., Diamond, A. L., & Smith, E. Effects of caffeine on enhancement of foveal simultaneous contrast. Journal of Experimental Psychology, 1961, 61, 18-22.

14. Lewis, A. J. (Ed.). Modern Drug Encyclopedia and Therapeutic Index. New York: The Dun-Donnelly Publishing Corp., 1973, P. 116.

15. Maiti, A., & Domino, E. F. Effects of methylated xanthines on the neuronally isolated cerebral cortex. Experimental Neurology, 1961, 3, 18-31.

16. Martinek, R. G., & Wolman, W. Xanthines, tannins, and sodium in coffee, tea and cocoa. Journal of the American Medical Association, 1955, 158, 1030-1031.

17. Matthias, H., & Erdmann, D. The action of caffeine on conditioned reflex reactions of rats and on an experimental derangement of the nervous system. Pharmazie, 1957, 12, 561-567. (Psychological Abstracts, 1959, 33, No. 3990.)

18. McFarland, R. A., Human Factors and Air Transport Design. New York: McGraw-Hill Book Co., 1946, p. 234.

19. McFarland, R. A., Halperin, M. H., & Niven, J. I. Visual thresholds as an index of the modification of the effects of anoxia by glucose. American Journal of Physiology, 1945, 144, 378-388.

20. Myzinikov, N. M. Sensitivity of the olfactory analyzer in service dogs and methods of enhancing it. Zh. vyssh. nervn. Deiatel'., 1958, 8, 744-750. (Psychological Abstracts, 1960, 34, No. 607.)

21. Pare', W., The effect of caffeine and seconal on a visual discrimination task. Journal of Comparative and Physiological Psychology, 1961, 54, 506-509.

22. Payne, R. B., & Hauty, G. T. The effects of experimentally induced attitudes upon task proficiency. Journal of Experimental Psychology 1954, 47, 267-273.

23. Regina, E. G., & Smith, G. M. Effects of caffeine on alertness in simulated automobile driving. Journal of Applied Psychology, 1974, 59, 483-489.

24. Seashore, R. H., & Ivy, A. C. The effects of analeptic drugs in relieving fatigue. Psychological Monographs, 1953, 67, No. 365, 1-16.

25. Sheard, C. The effects of smoking on the dark adaptation of rods and cones. Federation Proceedings, 1946, 5, 94.

26. Stanley, W. C., & Schlosberg, H. The psychophysiological effects of tea. Journal of Psychology, 1953, 36, 435-448.

27. The United States Pharmacopeia. The Pharmacopeia of the United States. Easton, Pa.: Mack Printing Co., 1965, p. 85.

28. Thornton, G. R., Holck, H. G. B., & Smith, E. L. The effect of benzedrine and caffeine upon performance of certain psychomotor tests. Journal of Abnormal and Social Psychology, 1939, 34, 96-113.

29. Walsh, J. W. T. Photometry. Toronto, Canada: General Publishing Co., Ltd., 1958, p. 137.

30. Weiss, B., & Laties, V. G. Enhancement of human performance by caffeine and amphetamines. Pharmacology Review, 1962, 14, 1-36.

31. Zimbardo, P. G., & Barry, H., III. Effects of caffeine and chlorpromazine on the sexual behavior of male rats. Science, 1958, 127, 84-85.

APPENDIX A

Mean Thresholds Obtained in Experiment I

for Each Treatment in Each S

Table A 1

Mean Thresholds (log ft.-L) Obtained in Experiment I
For Each Treatment in Each $\underline{S}$

Time Interval (min.)	Subject								
	T.M.			G.L.			S.H.		
	Placebo	100 mg	300 mg	Placebo	100 mg	300 mg	Placebo	100 mg	300 mg
0 - .5	-1.21	-1.17	-1.17	-1.06	-1.00	-1.11	-1.56	-1.40	-1.52
.5 - 1	-1.68	-1.47	-1.61	-1.50	-1.55	-1.29	-2.07	-2.03	-2.08
1 - 1.5	-1.93	-1.95	-2.00	-1.94	-1.96	-1.83	-2.30	-2.27	-2.31
1.5 - 2	-2.00	-2.02	-2.08	-2.04	-2.05	-2.05	-2.58	-2.49	-2.38
2 - 2.5	-2.04	-2.10	-2.10	-2.11	-2.09	-2.12	-2.62	-2.62	-2.57
2.5 - 3	-2.15	-2.15	-2.20	-2.19	-2.18	-2.20	-2.70	-2.72	-2.70
3 - 3.5	-2.19	-2.24	-2.28	-2.24	-2.25	-2.25	-2.85	-2.84	-2.81
3.5 - 4	-2.27	-2.35	-2.34	-2.27	-2.32	-2.37	-2.91	-2.96	-2.88
5	-2.55	-2.67	-2.66	-2.47	-2.48	-2.51	-3.14	-3.15	-2.99
7	-3.12	-3.18	-3.24	-2.56	-2.87	-2.98	-3.60	-3.80	-3.67
9	-3.63	-3.67	-3.65	-3.28	-3.29	-3.54	-4.10	-4.22	-4.16
11	-3.88	-4.18	-4.25	-3.89	-3.92	-4.07	-4.60	-4.75	-4.56
13	-4.35	-4.46	-4.54	-4.32	-4.23	-4.46	-4.94	-4.97	-4.76
15	-4.50	-4.68	-4.80	-4.49	-4.69	-4.76	-4.97	-5.06	-5.04
17	-4.60	-4.84	-4.88	-4.76	-4.82	-4.87	-5.08	-5.14	-5.22
19	-4.82	-4.90	-4.97	-4.94	-4.97	-4.94	-5.18	-5.23	-5.18
21	-4.80	-4.98	-5.03	-4.94	-4.99	-4.97	-5.15	-5.17	-5.21
23	-4.90	-5.05	-5.02	-4.98	-5.01	-5.02	-5.19	-5.27	-5.22
25	-4.94	-5.06	-5.02	-5.02	-5.05	-5.04	-5.25	-5.30	-5.27
27	-4.94	-5.00	-5.07	-5.07	-5.08	-5.08	-5.20	-5.25	-5.31
29	-4.98	-5.04	-5.11	-5.10	-5.08	-5.10	-5.24	-5.33	-5.35

APPENDIX B

Mean Thresholds O' tained in Experiment II

for Each Treatment in Each S

Table B1

Mean Threshold (log ft.-L) Obtained in Experiment II
For Each Treatment in Each S

Time Interval (min.)	D.V. Decaff.	D.V. Caff.	B.F. Decaff.	B.F. Caff.	J.S. Decaff.	J.S. Caff.
0 - .5	-1.47	-1.47	-1.75	-1.74	-1.65	-1.64
.5 - 1	-2.15	-2.12	-1.37	-2.19	-2.09	-2.19
1 - 1.5	-2.41	-2.49	-2.55	-2.55	-2.32	-2.37
1.5 - 2	-2.54	-2.64	-2.63	-2.68	-2.44	-2.38
2 - 2.5	-2.68	-2.78	-2.74	-2.82	-2.44	-2.47
2.5 - 3	-2.76	-2.74	-2.89	-2.94	-2.53	-2.47
3 - 3.5	-2.80	-2.90	-2.91	-2.95	-2.53	-2.46
3.5 - 4	-2.87	-2.90	-3.06	-3.06	-2.63	-2.55
5	-3.01	-3.03	-3.22	-3.22	-2.73	-2.75
7	-3.51	-3.42	-3.79	-3.87	-3.06	-3.07
9	-4.08	-4.02	-4.17	-4.28	-3.69	-3.67
11	-4.56	-4.53	-4.60	-4.69	-4.24	-4.19
13	-4.80	-4.93	-4.90	-5.03	-4.64	-4.66
15	-5.20	-5.22	-5.04	-5.16	-4.89	-4.98
17	-5.25	-5.29	-5.12	-5.23	-5.12	-5.13
19	-5.29	-5.32	-5.11	-5.32	-5.15	-5.17
21	-5.36	-5.38	-5.31	-5.41	-5.21	-5.21
23	-5.43	-5.42	-5.35	-5.40	-5.28	-5.23
25	-5.43	-5.53	-5.46	-5.47	-5.30	-5.31
27	-5.39	-5.55	-5.40	-5.53	-5.20	-5.21
29	-5.43	-5.46	-5.38	-5.50	-5.23	-5.27

APPENDIX C

Ss Grouped According to Coffee Consumption and Smoking Habits

Table C1

Ss Grouped According to Coffee Consumption
and Smoking Habits

Smoking Habit	Coffee Consumption (cups/day) 2 - 4	5 - 8
Smoker		S D.V. S J.S.
Non-Smoker	S T.M.** S G.L.** S B.F.*	S S.H.*

* Indicates one occurrence of caffeine enhancement effect.
** Indicates two occurrences of caffeine enhancement effect.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

(14) NAMRL-1235

2. GOVT ACCESSION NO.

3. ~~RECIPIENT'S~~ CATALOG NUMBER

(9)

4. ~~TITLE (and Subtitle)~~

(6) The Effect of Caffeine on Human Dark Adaptation

5. ~~TYPE OF REPORT & PERIOD COVERED~~

Interim rept.,

6. ~~PERFORMING~~ ORG. REPORT NUMBER

7. AUTHOR(s)

(10) Tommy R. Morrison ~~and~~ Gerald M. Long

8. CONTR~~ACT OR GRANT NUMBER(s)~~

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

MF51.524.004-2011

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Medical Research and Development Command
National Naval Medical Center
Bethesda, Maryland 20034

12. REPORT DATE

6 April [redacted] 1977

13. NUMBER OF PAGES

35

14. MON~~ITORING AGENCY NAME & ADDRESS~~(if different from Controlling Office)

(11) 6 Apr 77 (12) 33p.

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(16) F51524

17. DISTRI~~BUTION STATEMENT (of the abstract~~ entered in Block 20, if different from Report)

(17) MF51524004

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Caffeine, dark adaptation, detection thresholds, rod-cone break, vision.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

406061

1B

20. adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Morrison, Tommy R., LT MSC USN
Gerald M. Long, LT MSC USNR 1977

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN
Gerald M. Long, LT MSC USNR 1977

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN
Gerald M. Long, LT MSC USNR 1977

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break

Morrison, Tommy R., LT MSC USN
Gerald M. Long, LT MSC USNR 1977

THE EFFECT OF CAFFEINE ON HUMAN DARK ADAPTATION. NAMRL 1235
Pensacola, Florida 32508: Naval Aerospace Medical Research Laboratory. April 1977

The consumption of caffeine by naval personnel in the operational environment is extensive and frequent. In particular, pilots, aircrewmen, watchstanders, and drivers often consume coffee prior to their performance of missions or tasks at night. The present two experiments were designed to investigate the effects of caffeine upon the absolute detection thresholds during dark adaptation. Within certain subjects caffeine consumption resulted in lower detection thresholds. The caffeine enhancement effect was significant only during the portion of dark adaptation following the rod-cone break. No evidence was found for a detrimental effect of caffeine on dark adaptation.

Vision
Caffeine
Dark Adaptation
Detection Thresholds
Rod-cone Break